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THESIS

AN ANALYSIS OF MARINE CORPS BEYOND LINE OF SIGHT WIDEBAND SATELLITE COMMUNICATIONS REQUIREMENTS

by

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AN ANALYSIS OF MARINE CORPS BEYOND LINE OF SIGHT WIDEBAND SATELLITE COMMUNICATIONS REQUIREMENTS

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TABLE OF CONTENTS

LIST OF FIGURES

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LIST OF TABLES

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LIST OF ACRONYMS AND ABBREVIATIONS

ACE.....aviation combat element
AEHF.....Advanced Extremely High Frequency
BN.....battalion
C2.....command and control
CBA.....capabilities-based assessment
CDD.....capability development document
CE.....command element
CJCS.....Chairman of the Joint Chiefs of Staff
CLB.....combat logistics battalion
CLR.....combat logistics regiment
CMC.....Commandant of the Marine Corps
CNO.....Chief of Naval Operations
COMDT COGARD.....Commandant, United States Coast Guard
COMMSATCOM.....commercial satellite communications
CONOPS.....concept of operations
COTS.....commercial off-the-shelf
CPD.....capability production document
CPI.....Continuous Process Improvement
DAGR.....Defense Advanced Global Positioning System (GPS) Receiver
DCR.....DOTMLPF change recommendation
DDS.....data distribution suite
DoD.....Department of Defense
DON.....Department of the Navy
DOTMLPF.....doctrine, organization, training, materiel, leadership and education, personnel, and facilities
DSCS.....Defense Satellite Communications System
DTG.....digital trunk group (digital transmission group)
ECCS.....expeditionary command and control suite
EHF.....extremely high frequency
ETSSP.....Enhanced Tactical Satellite Signal Processor
FLTSAT.....fleet satellite
GBS.....Global Broadcast Service
GCE.....ground combat element
GFE.....government-furnished equipment
GIG.....Global Information Grid
GMF.....ground mobile force
GPS.....Global Positioning System
ICD.....initial capabilities document
JCIDS.....Joint Capabilities Integration and Development System
JFC.....joint force commander
JWICS.....Joint Worldwide Intelligence Communications System
Ka.....Kurtz-above Band

KPP.....key performance parameter
KSA.....key system attribute
Ku.....Kurtz-under Band
LCE.....logistics combat element
LMST.....Lightweight Multiband Satellite Terminal
LOS.....line of sight
LSS.....Lean Six Sigma
MAGTF.....Marine air-ground task force
MACS.....Marine air control squadron
MARCORSYSCOM.....Marine Corps Systems Command
MASS.....Marine air support squadron
MAW.....Marine aircraft wing
Mbps.....megabits per second
MCDP.....Marine Corps doctrine publication
MCS.....MAGTF communications system
MCWP.....Marine Corps warfighting publication
MEB.....Marine expeditionary brigade
MEF.....Marine expeditionary force
MEU(SOC).....Marine expeditionary unit (special operations capable)
MILSATCOM.....military satellite communications
MILSTAR.....military strategic and tactical relay system
MLG.....Marine logistics group
MOE.....measure of effectiveness
MOP.....measure of performance
MTACS.....Marine tactical air command squadron
MWCS.....Marine wing communications squadron
NASA.....National Aeronautics and Space Administration
NAVSTAR.....Navigation Satellite Timing and Ranging
NDS.....National Defense Strategy
NIPR.....Non-Secure Internet Protocol Router
NMS.....National Military Strategy
NRZ.....non-return-to-zero
NSS.....National Security Strategy
OEF.....Operation ENDURING FREEDOM
OIF.....Operation IRAQI FREEDOM
ORD.....operational requirements document
OTP.....on the pause
PEI.....principal end item
PNT.....positioning, navigation, and timing
POS/NAV.....position and navigation
REGT.....regiment
SAASM.....selective availability anti-spoof module
SATCOM.....satellite communications
SIPR.....Secure Internet Protocol Router
SMART-T.....Secure Mobile Antijam Reliable Tactical Terminal

STEP.....standardized tactical entry point
SWAN.....Support Wide Area Network
TGRS.....Transportable Ground Receive Suite
TRC.....tactical radio communication
TRI-TAC.....Tri-Service Tactical Communications Program
TROPO.....tropospheric scatter
TSSR.....tropospheric scatter (TROPO)-satellite support radio
TSST.....Tactical SHF Satellite Terminal
UFO.....ultrahigh frequency follow-on
UHF.....ultrahigh frequency
USMC.....United States Marine Corps
VSAT.....very small aperture terminal
WB.....wideband
WGS.....Wideband Global Satellite Communications

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I. INTRODUCTION

A. BACKGROUND

Satellite communications (SATCOM) are critical to military command and control (C2) because our operations are evolving to coordinate operations and effects between widely dispersed (beyond line of sight) forces.

> [*CJCS Instruction 6250.01 Satellite Communications* states that] SATCOM is critical for all military operations in support of the National Military Security Strategy [sic]. Military forces are dependent on space-based communications to provide essential information services in the execution of land, sea, air, and space operations. (CJCS, 1998, p. A-1)

SATCOM plays a key role in current operations, and that relationship will likely become more critical in future operations. Operating concepts, emerging technologies, and operational requirements continually evolve. The C2 infrastructure must progress at the same rate or faster in order to enable current operating concepts and meet the requirements of the warfighter. In essence, our evolving needs and requirements for C2 systems, capabilities, and associated attributes such as capacity, security, range, coverage, and timeliness should drive incremental improvements of our systems and capabilities. Beyond line of sight (LOS) is an important concept in military communications because conventional military doctrine has dictated that we mass forces; however, now we mass effects from fewer, more widely dispersed forces.

> [Doctrine is defined by Joint Publication 1-02 (JP 1-02) as the] fundamental principles by which the military forces or elements thereof guide their actions in support of national objectives. It is authoritative but requires judgment in application. (CJCS, 2010, p. 143)

Therefore, capabilities in the domain of beyond LOS systems, such as wideband (WB) SATCOM, must periodically be assessed for alignment with relevant strategy, policy, and doctrinal publications.

This thesis will examine the current *National Security Strategy* (NSS) to gain insight into national goals and priorities, and their impact on future military operations. The United States Marine Corps (USMC) must be prepared to meet all future challenges,

and SATCOM capabilities are a key enabler. Department of Defense (DoD) and Department of the Navy (DON) strategy documents, along with USMC doctrinal publications, drive how the USMC operates. They also have an impact on planning for future acquisitions. A clear understanding of specific policy and doctrinal requirements allows for an accurate assessment of what beyond LOS WB SATCOM capabilities the USMC requires in order to prepare for the future.

A clear understanding of desired capabilities allows for an examination of the SATCOM interoperability requirements. In a joint and coalition environment consisting of numerous systems, it is vital to ensure that the systems provide requirements-based capabilities and are interoperable. JP 1-02 defines coalition as "An ad hoc arrangement between two or more nations for common action" (CJCS, 2010, p. 76). Joint "connotes activities, operations, organizations, etc., in which elements of two or more Military Departments participate" (CJCS, 2010, p. 243). These definitions provide the context for understanding the interoperability requirements. A clear understanding of requirements is crucial to meeting the needs of all stakeholders in a joint and coalition force.

In addition, this thesis will suggest some best practices that should be applied in order to get the most value out of SATCOM acquisitions. Such best practices include continuous process improvement (CPI), product lines, and capability portfolio management.

The general area of research is the concept of operations (CONOPS) for USMC beyond LOS WB SATCOM. This research entails an examination of all pertinent national, DoD, and service-specific documents that outline strategy, policy, concepts, and provide vision for future warfighting requirements. The *Marine Corps Vision and Strategy 2025* predicts that future missions will cover a broad range of operations against geographically dispersed enemies (USMC, 2008, p. 13). There is no current beyond LOS WB SATCOM CONOPS describing how to leverage such capabilities in support of future USMC plans. The thesis will focus on considerations for future beyond LOS WB SATCOM capabilities for the USMC. This thesis research is sponsored by Marine Corps Systems Command (MARCORSYSCOM).

B. PURPOSE

This thesis provides an analysis of a broad range of publications that extend from national level strategy documents down to service level doctrinal publications that specifically address how we conduct military operations. A guiding principle throughout our research is to look for the best ways to conduct operations in keeping with USMC doctrine. As we analyze beyond LOS SATCOM systems, our focus is to identify how they can best support the key tenets of the NSS and USMC doctrine with the goal of providing a foundation for a proposed CONOPS that is consistent with the framework provided in the policy documents.

Although SATCOM is a big part of beyond LOS systems, this thesis does not propose to limit the research to SATCOM systems. It will include aspects that illustrate how these beyond LOS systems fit in within the context of other related DoD and USMC systems. In addition, best practices will be discussed on a general level, not specific to certain systems. Issues discussed will be broad enough to apply to various programs.

C. RESEARCH QUESTIONS

This research primarily attempts to answer the following questions:

1. What does the current NSS suggest for the future of USMC SATCOM?

2. Given DoD and DON strategy and policy documents, and taking into account the NSS and USMC doctrinal principles, what are the recommended beyond LOS wideband SATCOM capabilities?

3. What are the interoperability requirements?

4. What industry and DoD acquisition best practices should be applied to get the recommended capabilities to the warfighter quickly and cost effectively?

D. BENEFITS OF THE STUDY

This thesis will provide an analytical foundation to help shape future USMC SATCOM operational concepts. It will also provide a schematic link that illustrates the interconnectedness between the tenets of the NSS and military CONOPS for beyond LOS

wideband SATCOM systems. Additionally, it may aid in planning for future SATCOM systems acquisitions or at the least help to shape USMC requirements that must be satisfied by new systems.

E. METHODOLOGY

The methodology used in this thesis research consisted of the following steps:

1. Analyzed DoD, DON, and USMC high-level policy documents and other publications related to or impacting commercial and military SATCOM use.

2. Assessed current USMC SATCOM systems and capabilities.

3. Analyzed capability considerations for future beyond LOS wideband SATCOM systems and capabilities that will best support USMC warfighting operations.

Based on the above literature analysis and the future capability considerations, the thesis provides a foundation for a proposed CONOPS for the USMC that will help to best leverage beyond LOS wideband SATCOM capabilities and get the most value out of current and future systems.

F. THESIS ORGANIZATION

This research is divided into five sections with Chapter I providing the background context and purpose for researching this topic. Chapter II offers an analysis of the NSS and other policy documents that drive operational capabilities. An analysis of the as-is state of USMC operational SATCOM systems and capabilities is presented in Chapter III. Chapter IV explores some future capability considerations, along with some interoperability concerns and best practices related to systems acquisitions. The final section, Chapter V, concludes the research and suggests areas for further study in the future.

II. ANALYSIS OF STRATEGY, POLICY, AND CONCEPTS

A. INTRODUCTION

This section provides an analysis of various high-level strategy, policy, and doctrinal publications, ranging from the national level to the service component level. The goal of this analysis is to extract key guiding principles that should be considered as we assess and define equipment capabilities. These include national objectives, directly stated or implied statements guiding military operations or equipment acquisitions, and statements either in support of or in opposition to the use and development of SATCOM.

> Achieving the objectives of the NMS [*National Military Strategy*] in an uncertain and complex environment requires a capabilities-based approach to force design and planning that focuses less on a specific adversary or where a conflict might occur and more on how an adversary might fight. This capabilities-based approach uses operating concepts to drive planning and to guide the development of warfighting capabilities. (CJCS, 2004, p. 3)

The information gleaned from the analysis of the strategy, policy, and doctrinal documents will serve as the foundation upon which to assess current USMC SATCOM capabilities and develop considerations for future USMC beyond LOS wideband SATCOM capabilities.

B. ANALYSIS OF NATIONAL DOCUMENTS

This section is devoted to analysis of documents from the Office of the President, the Office of the Secretary of Defense, and the Chairman of the Joint Chiefs of Staff (CJCS).

1. National Security Strategy

The *National Security Strategy* (NSS) of the United States of America is a document prepared periodically by the executive branch of the government which outlines the major national security concerns of the United States and how the administration plans to deal with them. President Barack Obama (2010) states, in his prefatory comments to the NSS, "we will maintain the military superiority that has

secured our country, and underpinned global security, for decades." The United States of America will continue to underwrite global security around the globe. The NSS recognizes that there is a fundamental connection between our national security and our national competitiveness (Office of the President, The, 2010, p. 1). Investments made in science and innovation will contribute to our strength (Office of the President, The, 2010, p. 2).

The NSS notes that we promote universal values by living them at home. This strategy includes supporting the spread of technologies that facilitate the freedom to access information. Successfully implementing the agenda described in the NSS requires that we "maintain our military's conventional superiority, while enhancing its capacity to defeat asymmetric threats" (Office of the President, The, 2010, p. 5). Military superiority should include a focus on information superiority because, while the NSS supports the spread of technologies that facilitate access to information, it also notes the following. "In the two decades since the end of the Cold War, the free flow of information, people, goods and services has accelerated at an unprecedented rate. This interconnection has empowered individuals for good and ill." (Office of the President, The, 2010, p. 7)

The NSS lists many threats to our national security, to include the vulnerability of space and cyberspace. "The space and cyberspace capabilities that power our daily lives and military operations are vulnerable to disruption and attack." (Office of the President, The, 2010, p. 8) Defending against these threats "requires networks that are secure, trustworthy, and resilient. Our digital infrastructure, therefore, is a strategic national asset, and protecting it—while safeguarding privacy and civil liberties—is a national security priority." (Office of the President, The, 2010, p. 27)

The NSS aims to update, balance, and integrate all of the tools of American power. Key actions and priorities in regards to Defense are summarized in the NSS as follows:

> We are strengthening our military to ensure that it can prevail in today's wars; to prevent and deter threats against the United States, its interests, and our allies and partners; and prepare to defend the United States in a wide range of contingencies against state and nonstate actors. We will continue to rebalance our military capabilities to excel at counterterrorism,

> counterinsurgency, stability operations, and meeting increasingly sophisticated security threats, while ensuring our force is ready to address the full range of military operations. This includes preparing for increasingly sophisticated adversaries, deterring and defeating aggression in anti-access environments, and defending the United States and supporting civil authorities at home. (Office of the President, The, 2010, p. 14)

The NSS offers the assurance that the military will continue "to have the necessary capabilities across all domains—land, air, sea, space, and cyber" (Office of the President, The, 2010, p. 22). The NSS promotes investments in science and innovation. It also supports maintaining American military superiority. Once again, the NSS notes that protecting our information and communication infrastructure is a national security priority (Office of the President, The, 2010, p. 31). These concepts can be linked together in the NSS section about economic prosperity, which states that, “we must also ensure that America stays on the cutting edge of the science and innovation that supports our prosperity, defense, and international technological leadership" (Office of the President, The, 2010, p. 28). Beyond that, the NSS says, "We must continue to encourage cutting-edge space technology by investing in the people and industrial base that develops them. We will invest in the research and development of next-generation space technologies and capabilities" (Office of the President, The, 2010, p. 31). To that end, the NSS can serve as a foundation upon which to develop new concepts, technologies, and hardware related to SATCOM. Additionally, since these capabilities and technologies are essential across national security and not just within the military, 1) the people who comprise the military will increasingly come from a culture that is intimately familiar with and demanding of broad access to information and, 2) industry will be working to meet these needs, and the military will be "swimming with the current" as opposed to working against it as we seek more and more capability.

2. National Space Policy of the United States of America

The *National Space Policy of the United States of America* (NSP) lends support to continued use of SATCOM as well. "Satellites contribute to increased transparency and

stability among nations and provide a vital communications path for avoiding potential conflicts" (Office of the President, The, 2010, p. 1).

The NSP also warns of serious challenges that we now face to our continued successful use of space. Two issues stand out as concerns. There are an increasing number of nations and organizations using space. In other words, space is getting more crowded with both systems and debris. In addition, the benefits of space permeate almost every aspect of our lives, and those space capabilities are interconnected. The shrinking margin for error in space, coupled with our growing dependence on space capabilities, means that the stakes are very high and that mishaps or irresponsible acts in space can result in damaging and very costly consequences (Office of the President, The, 2010, p. 1).

Despite the increasing risks, it appears that our dependence on the benefits provided by space systems will persist. One of the stated goals in the NSP for the United States is to, "Energize competitive domestic industries to participate in global markets and advance the development of: satellite manufacturing; satellite-based services; space launch; terrestrial applications; and increased entrepreneurship" (Office of the President, The, 2010, p. 4). In order to meet the directive's goals, the NSP states that all departments and agencies shall strengthen American leadership in space-related science, technology, and industrial bases.

> Departments and agencies shall: conduct basic and applied research that increases capabilities and decreases costs, where this research is best supported by the government; encourage an innovative and entrepreneurial commercial space sector; and help ensure the availability of space-related industrial capabilities in support of critical government functions. (Office of the President, The, 2010, p. 5)

In addition, the NSP provides specific guidance in regards to acquisition of space capabilities and services. The NSP favors commercial space capabilities and services – where they fully meet government agency requirements – in order to promote a robust domestic commercial space industry. Departments and agencies are directed to "purchase and use commercial space capabilities and services to the maximum practical extent" or to modify commercial solutions, to include use of inventive, nontraditional

arrangements such as public-private partnerships, unless there is a national security or public safety issue (Office of the President, The, 2010, p. 10).

It is worth noting that one of the other stated goals in the NSP mitigates some of the risks associated with continued reliance on space systems. The NSP calls for, "domestic and international measures to promote safe and responsible operations in space; improved information collection and sharing for space object collision avoidance; protection of critical space systems and supporting infrastructures, with special attention to the critical interdependence of space and information systems; and strengthening measures to mitigate orbital debris" (Office of the President, The, 2010, p. 4). The NSP also directs NASA and the DoD to "Pursue research and development of technologies and techniques, through the Administrator of the National Aeronautics and Space Administration (NASA) and the Secretary of Defense, to mitigate and remove on-orbit debris, reduce hazards, and increase understanding of the current and future debris environment" (Office of the President, The, 2010, p. 7).

Also in line with mitigating the risks associated with reliance on space systems—and this is vital now that we are "entangled" with our technologies (Hillis, 2010)—the NSP directs that the United States shall:

> • Assure space-enabled mission-essential functions by developing the techniques, measures, relationships, and capabilities necessary to maintain continuity of services;
>
> > −Such efforts may include enhancing the protection and resilience of selected spacecraft and supporting infrastructure;
>
> • Develop and exercise capabilities and plans for operating in and through a degraded, disrupted, or denied space environment for the purposes of maintaining mission-essential functions; and
>
> • Address mission assurance requirements and space system resilience in the acquisition of future space capabilities and supporting infrastructure. (Office of the President, The, 2010, p. 9)

In other words, despite our continued use, development of, and reliance upon space-based communications, the NSP indicates that we should give attention to designing, building, and operating our space systems (which includes the spacecraft, supporting ground

infrastructure, and the communications links between them), such that at least the critical functions are available to at least the essential users in a contested environment.

3. National Defense Strategy

The *National Defense Strategy* (NDS) is published periodically in order to update how the DoD will contribute to achieving the NSS objectives. Lessons learned from previous operations, along with an assessment of the strategic environment and the tools available to the DoD, provide the basis for the new NDS. The 2008 NDS is based upon the 2006 version of the NSS; it has been included among the documents analyzed for this thesis because it is the most current version available.

The NDS forecasts continued engagement across the globe. "Beyond our shores, America shoulders additional responsibilities on behalf of the world" (Office of the Secretary of Defense, 2008, p. 1). Space and cyber threats are listed among the challenges facing the United States.

> The United States, our allies, and our partners face a spectrum of challenges, including violent transnational extremist networks, hostile states armed with weapons of mass destruction, rising regional powers, emerging space and cyber threats, natural and pandemic disasters, and a growing competition for resources. The Department of Defense must respond to these challenges while anticipating and preparing for those of tomorrow. (Office of the Secretary of Defense, 2008, p. 1)

The NDS states that, "We must also consider the possibility of challenges by more powerful states. Some may actively seek to counter the United States in some or all domains of traditional warfare or to gain an advantage by developing capabilities that offset our own" (Office of the Secretary of Defense, 2008, p. 3).

> China is one ascendant state with the potential for competing with the United States. For the foreseeable future, we will need to hedge against China's growing military modernization and the impact of its strategic choices upon international security. It is likely that China will continue to expand its conventional military capabilities, emphasizing anti-access and area denial assets including developing a full range of long-range strike, space, and information warfare capabilities. (Office of the Secretary of Defense, 2008, p. 3)

With regards to China, the NDS says that American fielded combat capabilities should preserve and enhance U.S. national advantages over time (Office of the Secretary of Defense, 2008, p. 3).

> The Department will respond to China's expanding military power, and to the uncertainties over how it might be used, through shaping and hedging. This approach tailors investment of substantial, but not infinite, resources in ways that favor key enduring U.S. strategic advantages. At the same time, we will continue to improve and refine our capabilities to respond to China if necessary. (Office of the Secretary of Defense, 2008, p. 10)

Russia is another country that could have security implications for the United States due to its retreat from democracy and increasing intimidation of its neighbors (Office of the Secretary of Defense, 2008, p. 3 and 10).

The NDS notes that over the next twenty years, population, resource, energy, climatic, and environmental pressures could combine in unpredictable and complex ways with social, cultural, technological, and geopolitical change of unprecedented speed and scale to create greater uncertainty (Office of the Secretary of Defense, 2008, p. 4). The NDS paints a picture of a future world that is economically more interdependent, but also increasingly sensitive to crises and shocks as countries strive to balance energy demand for economic development with climate change. So, the U.S. Armed Forces will need to be able to fight on short notice, anywhere, anytime. SATCOM is currently the only way to meet the communications needs of this environment. When our first forces hit the ground in Afghanistan in late 2001—a distant, remote, mountainous country with no infrastructure—SATCOM was the only way to communicate with them.

The NDS proposes that developments within science and technology, while presenting some potential threats, "may reduce many of the pressures and risks suggested by physical trends" (Office of the Secretary of Defense, 2008, p. 5). The decisions we make regarding equipment and capabilities we develop should reduce the risks associated with the trends, and should allow the DoD to hedge against uncertainty; capabilities should provide agility, flexibility, and interoperability (Office of the Secretary of Defense, 2008, p. 5). This has significant implications for SATCOM capabilities.

As in the NSS, the NDS also notes that the flow of goods, services, people, technology and information grows every year, but that terrorists and others seek to exploit the openness brought about by globalization. As part of its overall strategy to protect the country, the U.S. Armed Forces will continue deployments at sea, in the air, on land, and in space (Office of the Secretary of Defense, 2008, p. 6). SATCOM is an important component that enables the continued use of this strategy.

One of the ways in which the DoD will achieve its objectives is by securing U.S. strategic access and retaining freedom of action. The NDS notes the following:

> For more than sixty years, the United States has secured the global commons for the benefit of all. Global prosperity is contingent on the free flow of ideas, goods, and services. The enormous growth in trade has lifted millions of people out of poverty by making locally produced goods available on the global market. Low barriers to trade also benefit consumers by reducing the cost of goods and allowing countries to specialize. None of this is possible without a basic belief that goods shipped through air or by sea, or information transmitted under the ocean or through space, will arrive at their destination safely. The development and proliferation of anti-access technologies and tactics threatens to undermine this belief. (Office of the Secretary of Defense, 2008, p. 16)

The above suggests that global prosperity depends partially on the ability to transmit information through space with a reasonable level of information assurance. It also suggests that the DoD considers space to be part of the global commons. The Outer Space Treaty (formally known as The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies) does indeed state that outer space shall be free for use by all states (United Nations, 2002, p. 4). "The United States requires freedom of action in the global commons and strategic access to important regions of the world to meet our national security needs" (Office of the Secretary of Defense, 2008, p. 16). The NDS implies, therefore, that SATCOM is considered by the DoD to be required for national security.

The NDS also states that the DoD will increasingly leverage and transform to a more agile continental U.S. based expeditionary total force (Office of the Secretary of Defense, 2008, p. 16). This has implications for design of SATCOM equipment.

Historically, the USMC has strived to be light and expeditionary. This trend should certainly continue, based on the NDS, as it develops SATCOM systems.

"Technology and equipment are the tools of the Total Force, and we must give our people what they need, and the best resources, to get the job done. First-class technology means investing in the right kinds of technology at the right time." (Office of the Secretary of Defense, 2008, p. 19) Accordingly, it can be said that the NDS lends support towards continued development of SATCOM technology for the USMC, as long as there is a legitimate need and it is in line with USMC operating concepts.

It should also be noted, however, that "China is developing technologies to disrupt our traditional advantages. Examples include development of anti-satellite capabilities and cyber warfare." (Office of the Secretary of Defense, 2008, p. 22) Indeed, in January of 2007, China fired a missile and struck an aging Chinese satellite orbiting at an altitude of 537 miles (Singer, Clark, 2007). Furthermore, a U.S.-China Economic and Security Review Commission contracted research paper entitled *An Assessment of China's Anti-Satellite and Space Warfare Programs, Policies and Doctrines* describes 30 Chinese-written proposals for anti-satellite capabilities to include jamming, missiles, laser beams, and plasma weapons.

> [In each of their books, three Chinese colonels] advocated covert deployment of a sophisticated antisatellite weapon system to be used against United States in a surprise manner without warning. Even a small scale antisatellite attack in a crisis against 50 US satellites [assuming a mix of targeted military reconnaissance, navigation satellites, and communication satellites] could have a catastrophic effect not only on US military forces, but of the US civilian economy. (Pillsbury, 2007, p. 3)

Consequently, the NDS mandates the following:

> The Department will invest in hedging against the loss or disruption of our traditional advantages, not only through developing mitigation strategies, but also by developing alternative or parallel means to the same end. This diversification parallelism is distinct from acquiring overmatch capabilities (whereby we have much more than an adversary of a similar capability). It will involve pursuing multiple routes to similar effects while ensuring that such capabilities are applicable across multiple mission areas. (Office of the Secretary of Defense, 2008, p. 22)

The above explicitly states that the DoD must diversify its equipment assets in order to have redundant and assorted capabilities. In other words, while the NDS allows for continued use of SATCOM, it also clearly requires that the military have alternate communications equipment that is similar in capability but not space-based. This has some implications for determining the right mix of communications capabilities. However, it does not negate the continued requirement for USMC SATCOM capabilities.

4. The National Military Strategy of the United States of America

The National Military Strategy of the United States of America (NMS) is a document published by the Chairman of the Joint Chiefs of Staff (CJCS). It is informed by the NSS and NDS, and provides strategic direction to the U.S. Armed Forces. "The NMS provides focus for military activities by defining a set of interrelated military objectives and joint operating concepts from which the Service Chiefs and combatant commanders identify desired capabilities" (CJCS, 2004, p. 2).

The NMS states that the following principles guide the development of joint operations concepts and capabilities: strategic agility, decisiveness, and integration with other instruments of power. It further directs that combatant commanders must consider these principles in planning and conducting operations. Agility is defined as "the ability to rapidly deploy, employ, sustain and redeploy capabilities in geographically separated and environmentally diverse regions" (CJCS, 2004, p. 7), a niche for which SATCOM is particularly well-suited. These principles and other guidance from the CJCS do not apply only to the people in the U.S. Armed Forces; they should also drive the development of equipment and capabilities that enable the joint force to meet its military objectives.

The NMS describes the security environment as a more complex and distributed battlespace, with a wider range of adversaries with access to technology (CJCS, 2004, p. viii). The NMS repeats the NDS in stating that the DoD "must work to secure strategic access to key regions, lines of communication and the “global commons” of international waters, airspace, space and cyberspace" (CJCS, 2004, p. 1). Again, as in the NDS, the NMS describes information assurance as a critical element of national security. "Military operations require information assurance that guarantees access to information systems

and their products and the ability to deny adversaries access to the same. Securing the battlespace includes actions to safeguard information and command and control systems" (CJCS, 2004, p. 18).

The NMS calls for increasingly joint and interoperable capabilities that combine the strengths of each service component and other agencies.

> Joint forces will require new levels of interoperability and systems that are "born joint," i.e., conceptualized and designed with joint architectures and acquisition strategies. This level of interoperability ensures that technical, doctrinal and cultural barriers do not limit the ability of joint commanders to achieve objectives. (CJCS, 2004, p. 15)

The above statement describes one of the strengths of military SATCOM, as there are no service component-specific MILSATCOM systems. In addition to interoperability, the NMS also touches on the importance of compatibility and information sharing. Such attributes may also impact SATCOM concepts.

> Achieving shared situational awareness with allies and partners will require compatible information systems and security processes that protect sensitive information without degrading the ability of multinational partners to operate effectively with US elements. Such information and intelligence sharing helps builds trust and confidence essential to strong international partnerships. (CJCS, 2004, p. 17)

The NMS calls for the U.S. Armed Forces to "win decisively" where necessary. This "will include actions to: destroy an adversary's military capabilities through the integrated application of air, ground, maritime, space and information capabilities" (CJCS, 2004, p. 14). It further states that the joint forces "require expeditionary capabilities with highly mobile forces skilled in flexible, adaptive planning and decentralized execution even when operating from widely dispersed locations". Only SATCOM can support this. Even though the U.S. government has very high capacity terrestrial communications across the globe (the Global Information Grid, or GIG), it cannot meet the expeditionary or mobile needs. Something is needed for the "last mile" and with dispersed forces, only SATCOM meets the beyond LOS need. A critical aspect is to then tie the beyond LOS SATCOM into the GIG so that the mobile, tactical user has access to services and products available through the GIG. SATCOM is less secure and

reliable and has much less capacity than the GIG. It should be used when no other capability exists and provide access to the GIG as soon as possible for those users needing Non-secure Internet Protocol Router (NIPR), Secure Internet Protocol Router, (SIPR), and Joint Worldwide Intelligence Communications System (JWICS)-type services.

The NMS elaborates on expeditionary capabilities in saying that "power projection requires assured access to theaters of operation and enhanced expeditionary capabilities that support operational maneuver from strategic distances" (CJCS, 2004, p. 16).

The NMS describes the desired attributes of the joint force as follows:

> • Fully Integrated—functions and capabilities focused toward a unified purpose.
>
> • Expeditionary—rapidly deployable, employable and sustainable throughout the global battlespace.
>
> • Networked—linked and synchronized in time and purpose.
>
> • Decentralized—integrated capabilities operating in a joint manner at lower echelons.
>
> • Adaptable—prepared to quickly respond with the appropriate capabilities mix.
>
> • Decision superiority—better-informed decisions implemented faster than an adversary can react.
>
> • Lethality—destroy an adversary and/or his systems in all conditions. (CJCS, 2004, p. 15)

The NMS supports actions that help create a more network-centric force and that lead to greater decision superiority (CJCS, 2004, p. 27). Decision superiority is supported by superior intelligence and the power of information technologies (CJCS, 2004, p. 16). Furthermore, "A networked force capable of decision superiority can collect, analyze and rapidly disseminate intelligence and other relevant information from the national to tactical levels, then use that information to decide and act faster than opponents" (CJCS, 2004, p. 16). "Battlespace awareness, combined with responsive

command and control systems, supports dynamic decision-making and turns information superiority into a competitive advantage adversaries cannot match" (CJCS, 2004, p. 19).

In addition, the NMS requires that the U.S. overseas presence be scalable in order to improve our ability to deal with uncertainty, enable rapid operations and allow forces to respond with greater speed than in the past (CJCS, 2004, p. 25). The NMS supports continued development of technology in saying the Armed Forces must "leverage innovation and technology and act decisively in pursuit of national goals" (CJCS, 2004, p. 15). The USMC must consider the attributes alluded to above as it develops its communications equipment concepts and requirements. These include attributes such as interoperability, mobility, netcentricity, adaptability, and scalability.

C. ANALYSIS OF SERVICE DOCUMENTS

This section is devoted to an analysis of maritime concepts and doctrine.

1. A Cooperative Strategy for 21st Century Seapower

A Cooperative Strategy for 21st Century Seapower is a unified maritime strategy, the first ever produced. It is jointly signed by the Commandant of the Marine Corps (CMC), the Chief of Naval Operations (CNO), and the Commandant of the Coast Guard (COMDT COGARD). The purpose of the document is to describe how the United States will apply seapower around the world in order to meet our strategic objectives. The document states that "Our Nation’s interests are best served by fostering a peaceful global system comprised of interdependent networks of trade, finance, information, law, people and governance" (CMC, CNO, & COMDT COGARD, 2007, p. 4). It implies a continued need for expeditionary and versatile forces such as the Marine Corps by noting that "the maritime domain—the world’s oceans, seas, bays, estuaries, islands, coastal areas, littorals, and the airspace above them—supports 90 percent of the world’s trade, it carries the lifeblood of a global system that links every country on earth" (CMC, CNO, & COMDT COGARD, 2007, p. 4).

2. Marine Corps Operating Concepts

The Marine Corps overarching operating capabilities are outlined succinctly in the *Marine Corps Operating Concepts* (MOC) manual. Some of the key underlying purposes of this publication are to inspire discussion, debate, and innovation (Marine Corps Combat Development Command, 2010, p. 11). This document lays the foundation and provides reference points that guide future capability development and improve the way the Marine Corps operates and how it contributes to national security (Marine Administrative Message 415/10, 2010).

The U.S. Marine Corps role in implementing our national security policy is largely attributable to its naval character and responsiveness to missions across the range of military missions as defined by *Joint Publication 3-0 Joint Operations* (JP 3-0). In an effort to fulfill its role in meeting the Nation's evolving strategic needs, the Marine Corps has historically continuously revised its organization, training, and equipment (Marine Corps Combat Development Command, 2010, p. 2). Marine Corps forces perform a variety of missions across the range of military operations. The spectrum of military operations from a strategic context includes all military capabilities and is outlined in joint doctrine as types of military operations. The types of military operations span a wide spectrum and include major operations, enforcement of sanctions, counterinsurgency operations, and foreign humanitarian assistance to list a few. JP 3-0 defines the range of military operations and provides a comprehensive listing of the types of military operations.

> Military operations vary in size, purpose, and combat intensity within a range that extends from military engagement, security cooperation, and deterrence activities to crisis response and limited contingency operations and, if necessary, major operations and campaigns (CJCS, 2010, p. I-7).

Since the Marine Corps is organized, trained, and equipped to operate from the sea as an integral component of the naval team its actions are focused around assuring littoral access and responding to crisis. As a consequence, Marines will be faced with situations where they will have to rely on beyond line of sight systems and other non-terrestrial means to connect to the Global Information Grid. The MOC indicates that future missions for Marines will fall in a broad yet narrower range of operations that

include: Major Combat Operations (MCO), Preemptive MCO with limited forward access, Humanitarian Assistance (HA) Operations, and Counterinsurgency Operations (COIN) (Marine Corps Combat Development Command, 2010).

D. SUMMARY

The analysis of the strategies, policies, and concepts indicate that there will continue to be a requirement for robust SATCOM capabilities. Some of the key principles elucidated by the analysis of the documents include the following. National policies specifically encourage space and satellite-related activities, along with technologies that facilitate access to information. DoD documents warn of emerging threats to space-based systems but remain committed to their continued use, calling for capability diversification to counter threats. The Armed Forces are expected to become increasingly joint and expeditionary. Only SATCOM, with its capacity, range, and coverage, can legitimately support expeditionary forces; expeditionary forces are essential to meeting national and military objectives. The Marine Corps must be prepared to respond to a broad range of operations without much warning time. SATCOM enables that critical capability.

Desired characteristics for the forces and capabilities that were specifically mentioned in the documents include attributes such as secure, trustworthy, resilient, protected, expeditionary, mobile, agile, flexible, interoperable, rapidly deployable and redeployable, sustainable, compatible, integrated, networked, decentralized, adaptable, scalable, fast, versatile. Other attributes that should be considered include capacity, security, range, coverage, and timeliness. These considerations, in the context of the security environment and the vision for the future presented in the documents that were analyzed, form the basis upon which the next two chapters will discuss current USMC SATCOM capabilities and considerations for the future.

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III. ANALYSIS OF CAPABILITIES

A. INTRODUCTION

The current SATCOM capabilities are designed to support a commander's C2 requirements for all contingencies within the range of military operations. Since the Joint Capabilities Integration and Development System (JCIDS) process was put in place in June 2003, DoD systems and family of systems (FoS) have been designed and fielded to support operating capabilities that have been defined by the services. JCIDS employs a capabilities-based approach to identify current needs and future gaps in our ability to carry out joint warfighting missions and functions. The primary mechanism used to highlight and identify these requirements is the Capabilities Based Assessment (CBA) process. The CBA helps show the interrelationship between the JCIDS and Acquisition Processes.

> All CBAs are based on a framework of strategic guidance documents. The National Security Strategy (NSS), the National Strategy for Homeland Defense, the National Defense Strategy (NDS) and the National Military Strategy (NMS) provide the overarching description of the Nation's defense interests, objectives, and priorities. In addition, the Guidance for the Development of the Force, the Guidance for the Employment of the Force, and the most recent Quadrennial Defense Review Report contain further refinement of objectives and priorities, and help provide a framework for a CBA. (JCIDS Manual, 2009, p. A-1)

The CBA is important because it begins by identifying the mission or military problem to be assessed, the concepts to be examined, the timeframe in which the problem is being assessed, and the scope of the assessment (JCIDS Manual, 2009, p. A-3).

The conflicts in Iraq and Afghanistan that resulted in Operation ENDURING FREEDOM and Operation IRAQI FREEDOM have revealed some capability gaps and emphasized the need for dispersed, mobile, warfighting elements. There is also evidence that this dynamic applies to support elements as well. The dynamics of the modern battlefield continue to evolve and become more complex just as the requirements to support the associated command and control functions increase as well. There are several factors that contribute to the growth in requirements, such as the maturation and

development of new technologies and the adoption of new tactical procedures. The Enhanced Company Operation concept is a prime example of the latter. The ECO concept aims to maximize tactical flexibility through decentralized operations in dispersed, distributed environments (Price, 2009, p. 6). This dispersion and decentralization of forces increases the C2 requirements, particularly when operating in areas where traditional line of sight (LOS) communications are not feasible to support operational needs. In such cases, the deficiency must be filled with beyond line of sight communications assets.

The increasing use and reliance on beyond LOS systems may seem evident due to the technology and capabilities that are being leveraged by units within the military; however, a GAO report related to Commercial Communications Satellite Services put this growth and use into perspective.

> The Department of Defense (DoD) continues to rely on commercial satellite communications to plan and support operations. DoD use of commercial satellite bandwidth has increased over the past few years, making the department the largest single customer of commercial satellite bandwidth. (Government Accountability Office, 2006, p. 1)

The following two figures illustrate the categories of satellite systems and their salient characteristics, along with the relationship between MILSATCOM and COMMSATCOM.

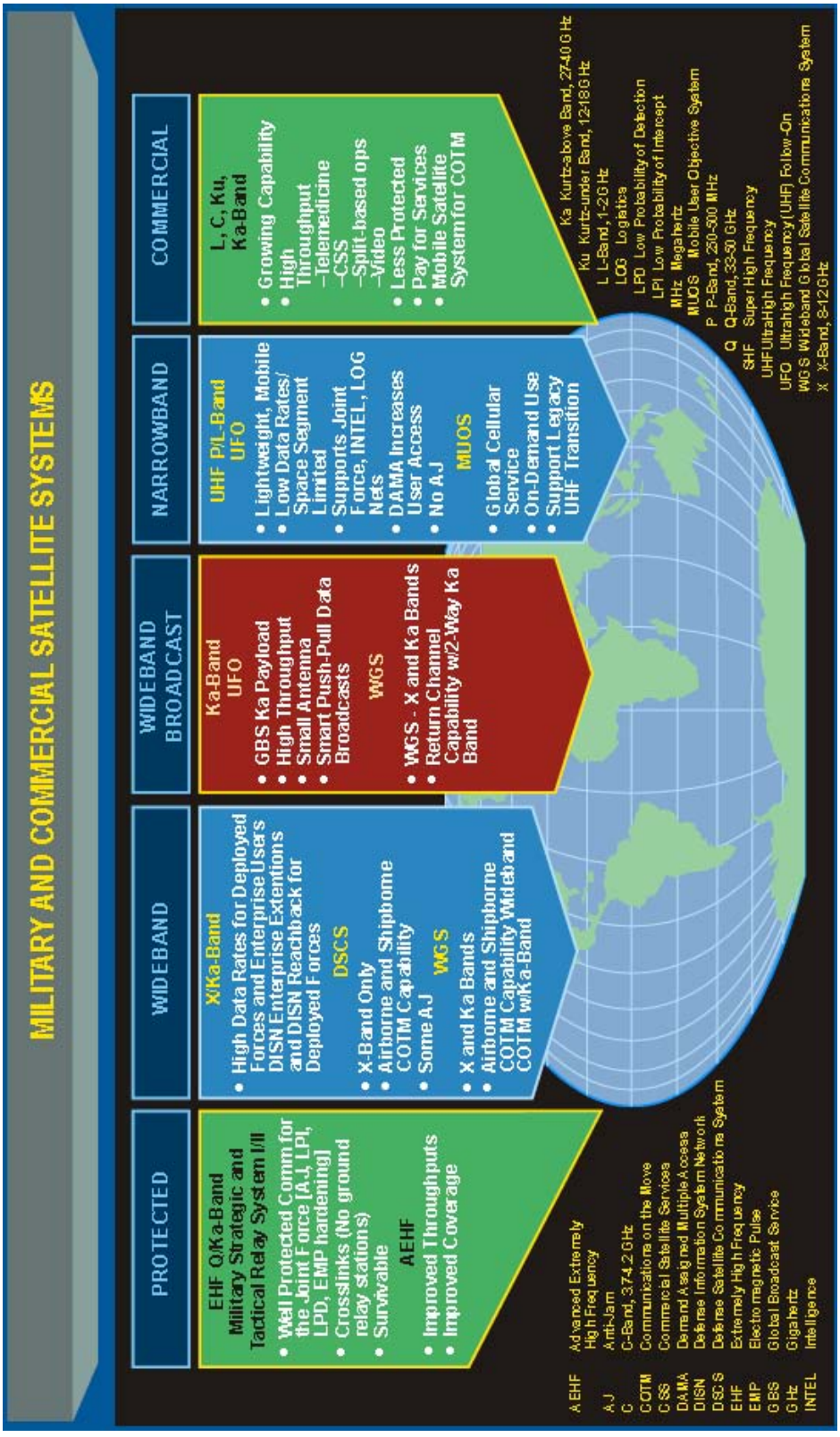

Figure 1. Military and Commercial Satellite Systems (From JP 3-14, 2009)

Figure 2. Satellite Communications Systems (From JP 6-0, 2010)

The trend lines for the bandwidth usage indicate that future requirements will only continue to grow. However, at present our ability to fulfill the bandwidth requirements

are somewhat constrained by the policies and equipment that we have today. If the Marine Corps had an emerging need to conduct to a mission within the range of military operations today it would be required to plan and execute based on the current inventory of systems and capabilities. In the terms of former Secretary of Defense Donald Rumsfeld, you go to war with the army you have, not the army you might want or wish to have at a later time (New York Times, 2004). Therefore, current USMC SATCOM capabilities are relegated to the aging limited inventory of legacy systems.

B. USMC MARINE AIR GROUND TASK FORCE (MAGTF)

The Marine Corps, within the Department of the Navy, is organized as a general purpose "force in readiness" to support national needs. Deploying for combat as combined-arms Marine air-ground task forces (MAGTFs), the Marine Corps provides the National Command Authorities (NCA) with a responsive force that can conduct operations across the spectrum of conflict.(MCCDC,1998, p. 1-1). The MAGTF is the fundamental construct for task-organizing and employing Marine Corps forces across the range of military operations (MCCDC, 2010, p.12).

> The MAGTF is the Marine Corps' principle organization for the conduct of all missions across the range of military operations. MAGTFs are balanced, combined-arms forces with organic ground, aviation, and sustainment elements. They are flexible, task-organized forces that can respond rapidly to a contingency anywhere in the world and are able to conduct a variety of missions. Although organized and equipped to participate as part of naval expeditionary forces, MAGTFs also have the capability to conduct sustained operations ashore. The MAGTF provides a combatant commander or other operational commander with a versatile expeditionary force that is capable of responding to a broad range of crisis and conflict situations. MAGTFs are organized, trained, and equipped to perform missions ranging from humanitarian assistance to peacekeeping to intense combat and can operate in permissive, uncertain, and hostile environments. They may be shore- or sea-based in support of joint and multinational major operations and/or campaigns. MAGTFs deploy as amphibious, air-contingency, or maritime prepositioning forces (MPFs), either as part of a naval expeditionary force or via strategic lift. They can present a minimal or a highly visible presence and are able to project combat power ashore in measured degrees or can provide secure staging areas ashore for follow-on forces. MAGTFs are prepared for immediate deployment overseas into austere operating environments, bringing all

> means necessary to accomplish the mission. When deployed aboard amphibious shipping, MAGTFs maintain a continuous presence at strategic locations around the globe and can be rapidly moved to and indefinitely stationed at the scene of potential trouble. The MAGTF provides the JFC with the capability of reconstitution, which is the ability of an expeditionary force to regenerate, reorganize, replenish, and reorient itself for a new mission without having to return to its home base. (MCCDC, 1998, p. 2-1)

In an effort to prepare for the future, the Marine Corps will explore revisions to MAGTF tables of organization and equipment, as well as select tactics, techniques, and procedures, in order to meet the challenges of the 21st century (MCCDC, 2010, p.6). This exploration of revisions would not be complete without considering the wideband beyond LOS systems currently employed by the MAGTF.

C. MAGTF COMMUNICATIONS

Marine Corps Warfighting Publication (MCWP) 3-40.3, MAGTF Communications System, presents doctrine, tactics, techniques, and procedures (TTP) for the employment of the communications system to support Marine air-ground task force (MAGTF) command and control (Marine Corps Combat Development Command, 2010, p. 3). The SATCOM systems within the MAGTF communications system (MCS) are a key component because they enable the warfighter to be globally interconnected to the GIG. SATCOM systems operating in the X-band, C-band, Ku-band, Ka-band, UHF, and EHF portions of the radio spectrum provide satellite connectivity to deployed tactical users by connecting to the DoD teleport and standardized tactical entry point (STEP). The STEP/teleports connect the joint force to the Defense Information Systems Network (DISN) long-haul services to provide a reachback capability for DISN voice, data, and video services across all frequency bands. The DISN provides the joint force commander (JFC) with the ability to access needed capabilities worldwide (Marine Corps Combat Development Command, 2010, p. 3-2 to 3-5).

> One of the most difficult C2 issues the Marine Corps now faces is the requirement to support a deployable Marine Corps component HQ with MCS personnel and equipment. The primary source of support is the communications battalion (COMM BN). The requirement to provide support to a deployed Marine Corps component HQ can have a significant

> effect on the availability of MCS resources to support the MAGTF. The MCS must be able to satisfy the C2 requirements of the expeditionary battlefield. It must provide MAGTF commanders and their staffs with the tools necessary to collect, process, analyze, and exchange information rapidly in support of operations planning and execution. These systems must make the necessary information available when and where it is needed on the battlefield. Employment of these systems must not adversely affect the MAGTF's freedom of action and mobility, and they must be reliable, flexible, responsive, and configurable to mission needs. The success of the MAGTF on the modern battlefield depends on designing, planning, and employing a communications system that satisfies the information needs of the MAGTF process. (Marine Corps Combat Development Command, 2010, p. 8)

In order to support the information exchange on the battlefield it is important that the communication system meet specific attributes that support and enable the warfighter on the battlefield. Whether this battlefield is defined as flat open terrain, desert highlands, jungles, mountains, at sea, or near the littorals, the communications system must be reliable, secure, timely, flexible, interoperable, and survivable. The Marine Air Ground Task Force (MAGTF) communications system publication elucidates these qualities in more detail so definitions are provided below to ensure clarity and to avoid ambiguity.

> Reliability - available when needed and perform as intended with low failure rates and few errors. Reliability is also attained by standardizing equipment and procedures and by building necessary electronic jamming and deception. Systems should perform reliably on board ships and aircraft, in garrison, and in austere field environments.
>
> Security - should provide security commensurate with the user's requirements and with the vulnerability of the transmission media to interception and exploitation. Security is achieved by using appropriate protection and cryptographic systems and transmission security techniques. It is also achieved by educating and training personnel in operational, management, and technical security procedures.
>
> Timeliness - should process and transfer information among decision makers rapidly enough to maintain a high tempo of operations. It should ensure that our decision and execution cycles remain ahead of any potential adversary's.

Flexibility - should be capable of being reconfigured quickly to respond to a rapidly changing environment. Flexibility can be obtained through system design or by using commercial facilities, mobile or transportable systems, or prepositioned facilities.

Interoperability - should enable information to be exchanged among all of the commanders and forces involved in an operation. The MCS also should possess the interoperability required to ensure information exchange in joint and multinational operations and in operations with other government agencies.

Survivability - refers to the measures taken to prevent disruption of the MCS by enemy interference or natural disaster. Survivability can be enhanced by the dispersal and protection of key nodes, physical and electromagnetic hardening, and redundancy of communication paths and information processing nodes. (Marine Corps Combat Development Command, 2010, p. 1-6)

D. CURRENT CAPABILITIES

The current supporting SATCOM systems inventory for the Marine Corps includes a range of systems and terminals that operate at various frequency ranges within the spectrum. In order to facilitate organization, satellite systems have been grouped in a manner that includes equipment and terminals that operate in the microwave, super high frequency, and extremely high frequency range. The Marine Corps currently has programs of record and family of systems that have been validated through JCIDS and designed to satisfy the current operating requirements of the warfighter. In the case of the range of operations outlined in the MOC, existing legacy systems will provide the communications backbone and interface to the Global Information Grid (GIG).

Systems Command, Product Group 12, is the organization that is tasked with the primary responsibility to deliver world class communications, intelligence, and networking systems and equipment to the operating forces that meet their requirements and expectation (Marine Corps Systems Command, 2010, Mission section). The Marine Corp Combat Development Command, Concept of Employment for SATCOM Operations publication describes the current SATCOM capabilities as consisting of a mixture of terminals with various capabilities. Some are both MILSATCOM and COMMSATCOM capable (dual-band, tri-band, and quad-band); some are

COMMSATCOM only, all with a mix of modem capabilities (Marine Corps Combat Development Command, p.6). Since the primary area of this research is focused on beyond line of sight satellite communications, a listing and description of the systems and equipment categorized under the satellite communications program is provided to document the systems that provide beyond line of sight communication and related SATCOM support for current operating capabilities.

1. Defense Advanced Global Positioning System (GPS) Receiver (DAGR)

The NAVSTAR Global Positioning System (GPS) is a space-based navigation and timing system made up of multiple satellites, a ground control system, and any number of navigation sets. The DAGR collects and processes satellite signals from the NAVSTAR GPS to provide position, velocity, and time (PVT) information, along with position reporting and navigation capabilities (Department of Defense, 2005, p. V).

The DAGR is a lightweight, hand-held, self-contained, selective availability anti-spoof module (SAASM) based GPS receiver. It provides Position, Velocity, Navigation, and Timing (PVNT) data using the GPS dual-frequency (L1/L2) Precise Positioning Service (PPS) for vehicular, hand-held, sensor and gun laying applications.

Defense Advanced Global Positioning System (GPS) Receiver (DAGR), AN/PSN-13/13A			
			
System Characteristics			
Spectrum	GPS L1 and L2 (1575.42 & 1227.60 MHz		
Concept of Employment	The primary operational mission of the DAGR is to provide precision navigation and timing data to land-based war fighting operations and operations other than war. These include ground personnel, indirect fire weapon systems, and armored vehicles. The DAGR can also be used as a secondary or supplemental aid to aviation-based missions which involve operations in low-dynamic aircraft, such as helicopters, and as an aid to navigation in water-borne operations, such as for combat swimmers, submarines, and watercraft.		
Life Cycle Configuration Control			
Initial Fielding	2Q FY06		
Quantity Fielded	7550		
Expected Replacement Timeframe	TBD		
MAGTF Distribution			
CE	**GCE**	**ACE**	**LCE**

Table 1. DAGR Fact Sheet (After MARCORSYSCOM Programs & Equipment, 2009)

2. Global Broadcast Service (GBS) Transportable Ground Receive Suite (TGRS)

GBS is a smart-push/user-pull SATCOM system that provides large volumes of information to deployed, or garrison forces. The AN/TSR-9 receives and disseminates GBS broadcasts at up to 23 Mbps, and is capable of processing both classified and unclassified information products such as: Imagery, Intelligence, Video (NTSC and Digital), Theater message traffic, Joint and service-unique news, Weather and MWR programming.

Each AN/TSR-9 TGRS consists of a Receive Terminal (including a 1-meter parabolic dish antenna), Receive Broadcast Manager Server, Power Controller Unit, Crypto (KG-250), Integrated Receiver-Decoder (for NTSC video), Managed Ethernet Switch, Unmanaged Ethernet Switch, Video Converter, and transit cases.

Global Broadcast Service (GBS) Transportable Ground Receive Suite (TGRS), AN/TSR-9			
			
System Characteristics			
Spectrum	Ka Band 20.2-21.2 GHz Ku Band 12.0-14.0 GHz		
Concept of Employment	The AN/TSR-9 satisfies a Marine Corps requirement for a global, high-throughput, one-way flow of voice, video, and data to Marine Forces either deployed or in garrison. GBS provides the capability to quickly disseminate large amounts of information to MAGTF, and s deployed with MAGTFs as a "first in" wideband communications resource.		
Life Cycle Configuration Control			
Initial Fielding	3Q FY06/2Q FY07		
Quantity Fielded	80		
Expected Replacement Timeframe	TBD		
MAGTF Distribution			
CE	**GCE**	**ACE**	**LCE**
Comm Bn, Intel Bn	Hq Bn, Inf Regt, Arty Regt	MWCS, Rad Bn	MLG H&S Bn(CLR)

Table 2. GBS Fact Sheet (After MARCORSYSCOM Programs & Equipment, 2009)

3. Ground Mobile Forces (GMF) Satellite Communications System

The AN/TSC-93C/D is a sheltered SHF SATCOM terminal capable of simultaneously transmitting and receiving up to 8.448 Mbps on a single multiplexed carrier. It provides voice and data communications to the ground, air, and logistics elements of a landing force. Baseband interfaces also provide connectivity with externally-multiplexed TRI-TAC equipment. The AN/TSC-93 can be used as a non-nodal terminal in point-to-point links with other SHF SATCOM terminals, or it can operate in conjunction with the AN/TSC-85 as part of a network. The AN/TSC-93 is configured to operate with the AS-3036_, AS-4429D Large Aperture Multiband Deployable Antenna (LAMDA) or AS-4429 Lightweight High Gain X-Band Antenna (LHGXA).

Ground Mobile Forces (GMF) Satellite Communications System, AN/TSC-93C/D			
			
System Characteristics			
Spectrum	Super High Frequency (SHF) 7.25-7.75 GHz (Rx) 7.9-8.4 GHz (Tx)		
Concept of Employment	The AN/TSC-93 and AN/TSC-85 combination provide landing force Marines with longhaul defense communications entry as well as intra-landing force communications. The AN/TSC-93 is deployed as a non-nodal, PTP terminal operating in a tactical communications system with the AN/TSC-85 terminal to provide direct field communications on tactical trunking networks. Up to four AN/TSC-93 terminals serve as spokes with one AN/TSC-85 in a hub-and-spoke configuration.		
Life Cycle Configuration Control			
Initial Fielding	1986		
Quantity Fielded	21		
Expected Replacement Timeframe	2012		
MAGTF Distribution			
CE	**GCE**	**ACE**	**LCE**
Comm Bn	N/A	N/A	N/A

Table 3. GMF Fact Sheet (After MARCORSYSCOM Programs & Equipment, 2009)

4. Lightweight Multi-Band Satellite Terminal (LMST)

The AN/USC-65(V)1 and AN/USC-65(V)2 are SHF quad-band (C-band, X-band, Ku-band, and Ka-band) wideband satellite communications ground terminals. The LMST provides a smaller, lighter, modular, more flexible terminal with a hub and spoke capability. The LMST is packaged in two configurations consisting of three or four transit cases and one 2.5-meter antenna. It has the capability to simultaneously transmit two (one mission and one orderwire) communications carriers and receive seven (six mission and one orderwire) communications carriers through either the terminal's internal antenna or a user-supplied external antenna.

Lightweight Multi-Band Satellite Terminal (LMST), AN/USC-65(V)			
			
System Characteristics			
Spectrum	Super High Frequency (SHF) C-band (3.625-6.425 GHz) X-band (7.25-8.4 GHz) Ku-band (10.95-14.5 GHz) Ka-band (Rx only) (20.2-21.2 GHz)		
Concept of Employment	The LMST operates in a worldwide military tactical environment and provides SHF SATCOM transmission of baseband signals at the MARFOR/MEF HQ for termination at MSC HQ, DISN STEP/teleport, naval vessels, and Service or JTF HQs.		
Life Cycle Configuration Control			
Initial Fielding	2003		
Quantity Fielded	31		
Expected Replacement Timeframe	2025		
MAGTF Distribution			
CE	**GCE**	**ACE**	**LCE**
Comm Bn	N/A	Comm Sqdn	N/A

Table 4. LMST Fact Sheet (After MARCORSYSCOM Programs & Equipment, 2009)

5. Phoenix Tactical SHF Satellite Terminal (TSST)

The AN/TSC-156 Phoenix is a Quad-band Tactical Super High Frequency satellite communications terminal mounted on an M1152A1 vehicular platform. A second vehicle s provided for logistics support. Phoenix is capable of operating over military X-and Ka-band satellites and C- and Ku-band over commercial satellites. The Phoenix will support one network consisting of up to four enhanced tactical satellite processors (ETSSP) multiplexed full-duplex links. The Phoenix is configured to operate with either the system's internal antenna in C-, X-, Ku-, and Ka-band, or with the AS-4429/TSC Large Aperture Antenna (LAA) in X-band, but not simultaneously.

<table>
<tr><th colspan="4">Phoenix Tactical SHF Satellite Terminal (TSST), AN/TSC-156</th></tr>
<tr><td colspan="4">  </td></tr>
<tr><th colspan="4">System Characteristics</th></tr>
<tr><td>Spectrum</td><td colspan="3">Super High Frequency (SHF)
C-band (3.625-6.425 GHz)
X-band (7.25-8.4 GHz)
Ku-band (10.95-14.5 GHz)
Ka-band (20.2-31 GHz)</td></tr>
<tr><td>Concept of Employment</td><td colspan="3">The Phoenix operates in a world-wide military tactical environment and provides SHF SATCOM transmission of baseband signals at the MARFOR/MEF HQ for termination at MSC HQ, DISN STEP/teleport, naval vessels, and Services or JTF HQs.</td></tr>
<tr><th colspan="4">Life Cycle Configuration Control</th></tr>
<tr><td>Initial Fielding</td><td colspan="3">2007</td></tr>
<tr><td>Quantity Fielded</td><td colspan="3">24</td></tr>
<tr><td>Expected Replacement Timeframe</td><td colspan="3">2025</td></tr>
<tr><th colspan="4">MAGTF Distribution</th></tr>
<tr><th>CE</th><th>GCE</th><th>ACE</th><th>LCE</th></tr>
<tr><td>Comm Bn</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
</table>

Table 5. TSST Fact Sheet (After MARCORSYSCOM Programs & Equipment, 2009)

6. Tropospheric Scatter Microwave Radio Terminal

The AN/TRC-170 is a transportable, self-enclosed troposcatter terminal (multichannel) capable of transmitting and receiving digital data over varying distances (up to 100 miles). This terminal is comprised of modular electronic equipment in various configurations with government-furnished equipment (GFE) multiplexers and cryptographic items all housed in a modified S-250/G shelter.

Tropospheric Scatter Microwave Radio Terminal AN/TRC-170			
			
System Characteristics			
Spectrum	Microwave Frequency 4.4-5.0 GHz		
Concept of Employment	The AN/TRC-170 provides interswitch transmission links up to 100 miles in range. It will normally be used by the MAGTF HQs and ACE.		
Life Cycle Configuration Control			
Initial Fielding	P3I-2QFY05		
Quantity Fielded	152		
Expected Replacement Timeframe	TBD		
MAGTF Distribution			
CE	**GCE**	**ACE**	**LCE**
Comm Bn	N/A	MACG, MAW	N/A

Table 6. TRC-170 Fact Sheet (After MARCORSYSCOM Programs & Equipment, 2009)

7. Secure Mobile Anti-jam Reliable Tactical Terminal (SMART-T) and Extremely High Frequency (EHF) SATCOM Planning Tool

The SMART-T provides tactical users with secure, jam-resistant data and voice satellite communications up to 2.24 Mbps via MILSTAR Extremely High Frequency (EHF) satellites and compatible payloads. In addition, the SMART-T provides Marine Air Ground Task Force (MAGTF) commanders with extremely reliable, survivable, long-haul connectivity for core command and control links. The AN/TSC-154A Advanced EHF (AEHF) upgrade, together with the AN/PYQ-14 AEHF planning tool will enable SMART-Ts to communicate over new AEHF satellites at up to 8 Mbps.

Secure Mobile Anti-jam Reliable Tactical Terminal (SMART-T) and Extremely High Frequency (EHF) SATCOM Planning Tool, AN/PSQ-17 & AN/PYQ-14			
			
System Characteristics			
Spectrum	Extremely High Frequency (EHF) Transmit (43.5-45.5 GHz) (EHF) Receive (20-21 GHz) (SHF)		
Concept of Employment	The SMART-T deploys in support of the Marine Expeditionary Force (MEF), Ground Combat Element (GCE) (Marine Division (MARDIV), Regiment, and Marine Expeditionary Brigade (MEB) / Marine Expeditionary Unit (MEU) nodes, but may be deployed to support any unit / task force at the commander's discretion. Any system interoperable with the Milstar or AEHF system may be the receiving terminal, affording protected connectivity to L-class Ship–, Joint Task Force–, or CONUS–based operational nodes.		
Life Cycle Configuration Control			
Initial Fielding	2002		
Quantity Fielded	42 Terminals/32 Planning Tools		
Expected Replacement Timeframe	2025		
MAGTF Distribution			
CE	**GCE**	**ACE**	**LCE**
Comm Bn	Comm Co	N/A	N/A

Table 7. SMART-T Fact Sheet (After MARCORSYSCOM Programs & Equipment, 2009)

8. Support Wide Area Network (SWAN)

SWAN family of systems (FoS) are an integrated commercial off-the-shelf (COTS) solution utilizing VSAT and networking components. SWAN is an OTP communications asset and can be set up in 30 minutes or less. SWAN fills a void of beyond LOS capability within the MAGTF communications infrastructure. SWAN-D comes in three versions; small, medium and trailer mounted. It consists of a RF Package and a network package. Version 2 and 3 can be used with a Master Reference Terminal (the network hub). The program of record is VSAT which will not include the Network Package. However, since the Data Distribution System Modular (DDS-M) (also a Network Package) will not be fielded until 2010, SWAN-D is being fielded as the interim principal end item (PEI).

Support Wide Area Network (SWAN)				
				
System Characteristics				
Spectrum	Super High Frequency (SHF) Ku-band: 14.0-14.5 GHz (Rx) 10.95-12.75 GHz (Tx)			
Concept of Employment	VSWAN is employed by Marine Forces in Iraq. This system provides the tactical commander with near-real time intra-theater streaming video on the battlefield. LSWAN provides the tactical commander with beyond line-of-sight communications capability intra-theater. HSWAN provides CJTF-HOA with long-range communication links within the CJTF Area of Operations. HSWAN provides NIPRNET, SIPRNET, and CENTRIXS e-mail and web services, with both secure and non-secure telephone connectivity. GSWAN provides remote teams in Iraq access into the tactical network (NIPRNET, SIPRNET, and DSN) via beyond line-of-sight SATCOM capability The Marine Corps will deploy the VSAT/SWAN-D at varying echelons within the MAGTF, including the Marine Expeditionary Force (MEF) Communications Battalions (supporting its associated MEUs) and the Major Subordinate Commands (to be task organ zed to lower echelons). The purpose of the VSAT/SWAN-D is to enable USMC intra-theater communications; to allow forward deployed elements to "break" the terrestrial line-of-sight tether and extend the r operations farther from their higher echelon command or to enable operations in terrain not conducive to Line-of-sight (LOS) operations.			
Life Cycle Configuration Control				
Initial Fielding	Dec 04/FY05			
Quantity Fielded	174			
Expected Replacement Timeframe	TBD			
MAGTF Distribution				
CE	**GCE**	**ACE**	**LCE**	
MEF, Comm Bn, MEU	Div Hq, Regt, Bn, Comm Co	MWCS, MASS, MACS, MTACS	MLG, CLR, CLB	

Table 8. SWAN Fact Sheet (After MARCORSYSCOM Programs & Equipment, 2009)

9. Tropo/Satellite Support Radio (TSSR)

The AN/GRC-239 Radio Set is a full duplex LOS microwave radio designed for quick deployable military applications. Also known as the TSSR, this radio's ease of set-up, transport, and reliable operations make it a great substitute for long cable runs. The TSSR is used with almost all existing TRI-TAC equipment. The TSSR is capable of providing connectivity to a single tri-service tactical (TRI-TAC) digital transmission group (DTG) with a data rate from 72-4608 KB/s. The TSSR can also support a balanced non-return to zero (NRZ) group from the AN/TAC-1 at a 6.144 MB/s data rate. An analog voice orderwire capability is also modulated onto the RF carrier.

Tropo/Satellite Support Radio (TSSR), AN/GRC-239			
			
System Characteristics			
Spectrum	Microwave Frequency 14.4-15.25 GHz		
Concept of Employment	The TSSR operates in a worldwide military tactical environment. The TSSR serves as a multi-channel transmission communication system for MAGTFs of all sizes. The system augments existing GMF satellite terminals. The TSSR is a solid state, FM, wideband microwave radio system designed to replace existing tactical CX-11230 dual coax al cable runs or TFOCA interconnecting the AN/TRC-170(V) (or other TRI-TAC equipment, including GMF) in remote locations.		
Life Cycle Configuration Control			
Initial Fielding	3QFY06		
Quantity Fielded	92		
Expected Replacement Timeframe	TBD		
MAGTF Distribution			
CE	**GCE**	**ACE**	**LCE**
MEF HQ, Comm Bn	MARDIV, HQ Bn, Comm Co	MWCS, MACG, MAW	MLG, H&S Bn

Table 9. TSSR Fact Sheet (After MARCORSYSCOM Programs & Equipment, 2009)

E. SUMMARY

This section highlights the systems and terminals that presently enable the Marine Corps to access the space-based domain. At this time, the USMC beyond line of sight access is essentially limited to five systems. The LMST, SMART-T, Phoenix, ECCS, and SWAN are the systems of record that provide inter-network, reach-down, and reach-back capability. Since many of the new advancements in technology are dependent on some sort of network or GIG connectivity it is critical that we focus on this area, particularly in the case of the Marine Corps since current systems are aging and reaching the end of their life cycle. The military reliance on SATCOM in the near term does not appear to be decreasing. In fact, a recent report from the Defense Science Board highlights spaced based capabilities as an area of serious importance that continues to exhibit increased vulnerabilities.

> The nation relies on space-based capabilities not only to meet the needs of joint military operations worldwide, but also to support diplomatic, informational, and economic efforts. Space is essential to strategic and tactical military communications; missile warning; intelligence; and position, navigation, and timing. Nevertheless, techniques to deny the use of space are proliferating. (Defense Science Board, 2009, p. 15)

This fact helps to emphasize the significance of the role that SATCOM plays in the tactical and operational environment and reinforces the notion that it should not be ignored. The Defense Science Board's warning concerning the vulnerabilities of space-based capabilities mirrors the warning contained in the NDS, which calls for diversification. These assessments indicate that future SATCOM acquisitions should be part of a larger set of heterogeneous communication systems that ensure redundancy in capabilities. Nevertheless, SATCOM will continue to play a vital role in USMC C2.

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IV. FUTURE CAPABILITY CONSIDERATIONS

A. INTRODUCTION

Since it is often difficult to predict with any degree of certainty the time, location, duration, and intensity of a military operation, SATCOM systems must provide for all contingencies. The military, intelligence, and other government agencies must rely on space-based systems to provide this connectivity for continuous operations globally without regard to the existing in-theater or regional telecommunications infrastructures (US Strategic Command, 2004, p. 2). SATCOM has become a necessity for deployed forces and this reliance has been reinforced by emerging COTS technology that supports warfighter requirements.

No discussion of requirements is complete without a clear understanding of the primary stakeholder. It may be useful to establish the statutory basis upon which the Marine Corps exists. It is important to understand the composition and functions of the USMC prior to making any assessments regarding SATCOM equipment capabilities. The composition and functions of the Marine Corps are codified in federal law.

> (a) The Marine Corps, within the Department of the Navy, shall be so organized as to include not less than three combat divisions and three air wings, and such other land combat, aviation, and other services as may be organic therein. The Marine Corps shall be organized, trained, and equipped to provide fleet marine forces of combined arms, together with supporting air components, for service with the fleet in the seizure or defense of advanced naval bases and for the conduct of such land operations as may be essential to the prosecution of a naval campaign. In addition, the Marine Corps shall provide detachments and organizations for service on armed vessels of the Navy, shall provide security detachments for the protection of naval property at naval stations and bases, and shall perform such other duties as the President may direct. However, these additional duties may not detract from or interfere with the operations for which the Marine Corps is primarily organized.
>
> (b) The Marine Corps shall develop, in coordination with the Army and the Air Force, those phases of amphibious operations that pertain to the tactics, technique, and equipment used by landing forces.

(c) The Marine Corps is responsible, in accordance with integrated joint mobilization plans, for the expansion of peacetime components of the Marine Corps to meet the needs of war. (Title 10 U.S. Code Section 5063, 2007, p. 1696)

B. FUTURE CAPABILITY CONSIDERATIONS

Prior to attempting to select an optimal system or family of systems that can meet the USMC operational mission requirements, it is essential to ensure that there is a basis for the terms used to describe the candidate system and its attributes. Since the JCIDS manual sets the guidelines and procedures for analyzing and developing ICDs, CDDs, CPDs, and DCRs it is important to list out a few characterizations to ensure a consistent understanding of the terminology and to provide the framework for the rationale applied towards answering the question of what are the recommended beyond LOS wideband SATCOM capabilities given the guiding principles outlined in the NSS and DoD strategy and policy documents, and taking into account the DON and USMC doctrinal concepts.

initial capabilities document (ICD) - Summarizes the CBA and recommends materiel or non-materiel approaches or approaches that are a combination of materiel and non-materiel to satisfy specific capability gaps. It defines the capability gap(s) in terms of the functional area, the relevant range of military operations, desired effects, time, and DOTMLPF and policy implications and constraints. The ICD summarizes the results of the DOTMLPF analysis and the DOTMLPF approaches (materiel and non-materiel) that may deliver the required capability. The outcome of an ICD could be one or more joint DOTMLPF change recommendations or capability development documents. (CJCS, 2009, p. GL-10)

capability development document (CDD) - A document that captures the information necessary to develop a proposed program(s), normally using an evolutionary acquisition strategy. The CDD outlines an affordable increment of militarily useful, logistically supportable, and technically mature capability. The CDD may define multiple increments if there is sufficient definition of the performance attributes (key performance parameters, key system attributes, and other attributes) to allow approval of multiple increments. (CJCS, 2009, p.GL-6)

capability production document (CPD) - A document that addresses the production elements specific to a single increment of an acquisition program. The CPD defines an increment of militarily useful, logistically supportable, and technically mature capability that is ready for a

production decision. The CPD defines a single increment of the performance attributes (key performance parameters, key system attributes, and other attributes). (CJCS, 2009, p GL-6)

capability gaps - The inability to achieve a desired effect under specified standards and conditions through combinations of means and ways to perform a set of tasks. The gap may be the result of no existing capability, lack of proficiency or sufficiency in existing capability, or the need to replace an existing capability. (CJCS, 2009, p. GL-6)

capability need - A capability identified through the CBA, required to be able to perform a task within specified conditions to a required level of performance. (CJCS, 2009, p. GL-6)

key performance parameters (KPP) - Those attributes of a system that are considered critical or essential to the development of an effective military capability. KPPs must be measurable and testable to enable feedback from test and evaluation efforts to the requirements process. KPPs are validated by the Joint Requirements Oversight Council (JROC) for JROC Interest documents, by the Joint Capabilities Board for JCB Interest documents, and by the DOD component for Joint Integration, Joint Information, or Independent documents. Capability development and capability production document KPPs are included verbatim in the acquisition program baseline. (CJCS, 2009, p. GL-15)

key system attribute (KSA) - An attribute or characteristic considered crucial to achieving a balanced solution/approach to a system, but not critical enough to be designated a KPP. KSAs provide decision makers with an additional level of capability performance characteristics below the KPP level and require a sponsor 4-star, Defense agency commander, or Principal Staff Assistant to change. (CJCS, 2009, p. GL-15)

The terms defined above are common to the acquisitions domain and are very relevant to any consideration for future beyond LOS SATCOM capabilities, particularly since the solution to the SATCOM problem will not likely be solved by a non-material solution such as a change to DOTMLPF (doctrine, organization, training, materiel, leadership and education, personnel, and facilities). The common non-materiel approaches are alternate doctrinal approaches, alternate CONOPS, and policy alternatives. Although modifications to doctrine and CONOPS may be part of the solution, beyond LOS in the future is likely to be addressed by a material solution that results in an SATCOM acquisition program to deliver the required capability. However, the fielding of a candidate system could also require the consideration of non-material

alternatives to enable the system to work more effectively and provide more value to the warfighter. Some non-materiel approaches are defined below along with characterization of the term materiel solution.

> Alternative Doctrinal Approaches and Alternative CONOPS - Investigating alternative CONOPS is a JCIDS requirement. The baseline assessment should only consider doctrinal CONOPS, but the non-materiel approach assessment should consider doctrinal alternatives, particularly those documented in an approved joint concept. (CJCS, 2009, p. A-7)
>
> Policy Alternatives - A policy change that allows new applications of existing capabilities or modifies force posture to increase deterrence is always of interest and should be considered. (CJCS, 2009, p. A-7)
>
> materiel solution - Correction of a deficiency, satisfaction of a capability gap, or incorporation of new technology that results in the development, acquisition, procurement, or fielding of a new item (including ships, tanks, self-propelled weapons, aircraft, etc., and related software, spares, repair parts, and support equipment, but excluding real property, installations, and utilities) necessary to equip, operate, maintain, and support military activities without disruption as to its application for administrative or combat purposes. In the case of family of systems and system of systems approaches, an individual materiel solution may not fully satisfy a necessary capability gap on its own. (CJCS, 2009, p. GL-15)

The Marine Corps must also consider several operational factors in determining future SATCOM system requirements. The principal warfighting functions of maneuver, fires, intelligence, command and control, logistics, and force protection must not be ignored and should be factored into the decision process. Additionally, quality attributes such as suitability, reliability, supportability, and sustainability should be used as metrics to indicate how the system(s) should perform.

C. INTEROPERABILITY

CJCSI 6212.01E Interoperability and Supportability of Information Technology and National Security Systems provides key policies and procedures pertaining to interoperability needs within the JCIDS process. It describes interoperability as follows.

> The ability of systems, units or forces to provide data, information, materiel and services to and accept the same from other systems, units or forces and to use the data, information, materiel and services so exchanged

> to enable them to operate effectively together. IT and NSS interoperability includes both the technical exchange of information and the operational effectiveness of that exchanged information as required for mission accomplishment. Interoperability is more than just information exchange. It includes systems, processes, procedures, organizations, and missions over the lifecycle and must be balanced with IA. (CJCS, 2008, p. GL-15)

The instruction states that all programs of records require interoperability and supportability certification. It calls for program managers and military services to ensure that their systems and subsystems meet the following requirements.

> Interoperable with other DOD, Joint and Coalition systems, implement the DOD Net--Centric Data Strategy and Net-Centric Services Strategy policies, including participating in applicable Communities of Interest, within security constraints.
>
> Properly evaluated and certified for interoperability by the DISA (JITC). (CJCS, 2008, p. C-12)

It should be pointed out that there are some special considerations laid out for SATCOM terminals and radios. In some cases, SATCOM interoperability requirements may need to be confirmed with J-6 (CJCS, 2008, p. D-9). The need for interoperability within the domain of SATCOM is reiterated in *CJCS Instruction 6250.01 Satellite Communications*.

D. BEST PRACTICES

This section will briefly describe some best practices that can be applied towards future acquisition and management of systems. In some cases, these practices are in fact required by policy or directive. Regardless, it should be common sense for leaders and managers at all levels to seek out ways to promote efficiency and maximize value. The goal of this section is to put forth several concepts that might help provide a new or improved capability to the warfighter faster. It is not the aim of this section to provide a comprehensive review all best practices or even of those described herein; delving deeper is left up to the initiative of the individual reader. Rather, this section is intended to stimulate interest and discussion in continually improving the acquisitions process for the benefit of the warfighter on the front lines.

1. Practices Required by the National Space Policy

In regards to space system development and procurement, the NSP states that all departments and agencies shall:

> • Improve timely acquisition and deployment of space systems through enhancements in estimating costs, technological risk and maturity, and industrial base capabilities;
>
> • Reduce programmatic risk through improved management of requirements and by taking advantage of cost-effective opportunities to test high-risk components, payloads, and technologies in space or relevant environments;
>
> • Embrace innovation to cultivate and sustain an entrepreneurial U.S. research and development environment; and
>
> • Engage with industrial partners to improve processes and effectively manage the supply chains. (Office of the President, The, 2010, p. 6)

The NSP also directs all departments and agencies to strengthen interagency partnerships. Such partnerships, among other things, can help prevent unnecessary duplication of efforts and potentially reduce costs.

> Departments and agencies shall improve their partnerships through cooperation, collaboration, information sharing, and/or alignment of common pursuits. Departments and agencies shall make their capabilities and expertise available to each other to strengthen our ability to achieve national goals, identify desired outcomes, leverage U.S. capabilities, and develop implementation and response strategies. (Office of the President, The, 2010, p. 6)

2. Capability Portfolio Management

DoD Directive 7045.20 Capability Portfolio Management states that it is DoD policy that the Department of Defense shall use capability portfolio management. Capability portfolio management is described as "The process of integrating, synchronizing, and coordinating Department of Defense capabilities needs with current and planned DOTMLPF investments within a capability portfolio to better inform decision making and optimize defense resources" (Office of the Secretary of Defense, 2008, p. 8). The service components are required to "Ensure that their respective

decision forums, processes, policies, and procedures support capability portfolio management" (Office of the Secretary of Defense, 2008, p. 5).

> [Capability is defined as] the ability to achieve a desired effect under specified standards and conditions through a combination of means and ways across doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) to perform a set of tasks to execute a specified course of action. (Office of the Secretary of Defense, 2008, p. 8)

A capability portfolio is a collection of grouped capabilities. The purpose of capability portfolio management is to optimize capability investments across the defense enterprise (both materiel and non-materiel) and minimize risk in meeting the Department's capability needs in support of strategy. The process is accomplished by leveraging operational experts to identify issues, priorities, and capability and resource mismatches (gaps, shortfalls, and redundancies) (Office of the Secretary of Defense, 2008, pp. 1 and 2). The duties of a portfolio manager are described as follows.

> Provide recommendations or advice to appropriate DoD decision makers and forums regarding integration, coordination, and synchronization of capability requirements to capability investments. Evaluate capability demand (both warfighting and non-warfighting) against resource constraints, identify and assess risks, and suggest capability trade-offs within their capability portfolio to the Heads of the DoD Components, and to the DAWG through the following activities. (Office of the Secretary of Defense, 2008, p. 6)

In order to be able to do this, portfolio managers must be given access to and visibility of pertinent information and internal processes (Office of the Secretary of Defense, 2008, p. 5). This requires the full support of the leadership structure. Capability portfolio management can lead to cost savings and increasingly interoperable capabilities to support the forces.

3. Continuous Process Improvement

DoD Directive 5010.42 DoD-Wide Continuous Process Improvement (CPI)/Lean Six Sigma (LSS) Program states that it is DoD policy that Continuous Process Improvement (CPI)/Lean Six Sigma (LSS) shall be implemented across all of the military services. The objective of the DoD CPI/LSS program is to strengthen joint operational

Combatant Command and Military Department capabilities including making improvements in productivity, performance (availability, reliability, cycle time, investment, and operating costs), safety, flexibility, and energy efficiency. The directive says that "Each DoD Component should use CPI/LSS concepts and tools to improve the full range of processes and activities that comprise their operations, including decision-making processes and appropriate engagement with industrial base suppliers" (Office of the Secretary of Defense, 2008, p. 2). The services are directed to "implement CPI/LSS programs to improve overall effectiveness and efficiency across missions and functions to gain the broadest possible range of organizational improvements" (Office of the Secretary of Defense, 2008, p. 2). CPI/LSS concepts and tools should be applied to the full range of DoD organizations, to include combat, industrial, service, and office environments of headquarters, field, and operational organizations. As a result, this applies towards organizations that deal with acquisitions or managing programs.

Details on how to implement CPI/LSS are contained in the Continuous Process Improvement Transformation Guidebook. CPI comprises the application of tools and methods such as Lean Six Sigma and Theory of Constraints, with a value stream focus within the enterprise being transformed. In his prefatory memorandum institutionalizing CPI, Deputy Secretary of Defense England states that "The Secretary and I expect that every DoD organization is focused every day on improving the effectiveness of our support to the Warfighter" (Office of the Secretary of Defense, 2006, p. i). He goes on to specifically point out that CPI has improved the operating effectiveness of DoD logistics and acquisition activities. Some of the key tenets of CPI are keeping the customer in mind, being cost conscious, and staying receptive to new CPI concepts and tools as they evolve. Continuous improvement boils down to good leadership and management. Education, documentation, metrics, and periodic reviews are some of the necessary management practices to keep in mind as leaders implement CPI/LSS.

4. Product Lines

A product line can be a good approach to develop systems that will share many common features. It follows that systems with common features are likely to be more

interoperable, or at least more easily modified to be interoperable. Interoperability is a desired attribute in an increasingly joint and coalition environment. The Software Engineering Institute states that product lines can potentially improve productivity, quality, developmental time, and costs (http://www.sei.cmu.edu/productlines/). Product lines may also facilitate implementation of standards, which can lead to products of incrementally increasing capabilities and quality. This in turn helps to maximize value for the customer.

E. SUMMARY

Electrical engineer and computer scientist Daniel Hillis (2010) has made the following sobering assessment: "Our technology has gotten so complex that we no longer can understand it or fully control it." The NSS states that, "Technology will continue to bring with it new dangers" (Office of the President, The, 2010, p. 13). In an increasingly complex and dangerous security environment, it becomes even more challenging to ascertain the way forward especially for high-stakes, high-cost systems such as WB SATCOM. There are many factors that must be considered as the Marine Corps develops future SATCOM-related concepts and plans for new systems. The Marine Corps must take into account DoD and CJCS guiding principles and desired attributes, and also consider the context provided by the NSS. It must remain true to its doctrinal roots as the nation's expeditionary force in readiness. Yet, per the *Marine Corps Vision and Strategy 2025*, "it cannot assume there will be technological silver bullets or doctrinal formulas that ensure military success" (USMC, 2008, p. 13).

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V. CONCLUSIONS AND FUTURE WORK

A. CONCLUSION

The NSS suggests that there is still a future for SATCOM in the Marine Corps. SATCOM may become part of a larger set of communications assets that provide redundant capabilities, as called for in the NDS. However, SATCOM capabilities fill a unique niche for expeditionary forces that no other type of asset can fully duplicate. The USMC should continue to further develop and refine its SATCOM assets, while also looking into other options that can mitigate risks and threats described in the NDS. It should remain committed to its expeditionary character, as that is the trend for Armed Forces as described in the NMS. The Marine Corps operating concepts call for lighter, faster, more efficient end items. The documents analyzed for this thesis also highlighted the ever-increasing need for interoperability across the board, to include joint and coalition forces. Although a relatively low-density asset, interoperability should still be a consideration for SATCOM systems. Interoperability is a long-term goal that can be attained faster if it is considered early in the acquisition process for each new system. By applying concepts such as capability portfolio management and CPI, as described in the best practices section, SATCOM systems promise to provide ever increasing capabilities to the warfighter.

Upon commencement of this research we sought to explore national policy, doctrinal publications, and guiding instructions in an attempt to better understand the relationship and impact that these policy documents have on the development of beyond LOS SATCOM. Four fundamental questions were presented:

1. What does the current NSS suggest for the future of USMC SATCOM?

2. Given DoD and DON strategy and policy documents, and taking into account the NSS and USMC doctrinal principles, what are the recommended beyond LOS wideband SATCOM capabilities?

3. What are the interoperability requirements?

4. What industry and DoD acquisition best practices should be applied to get the recommended capabilities to the warfighter quickly and cost effectively?

This thesis addresses these questions within the content of the chapters, and the analysis of the relevant publications reveal that there is definitely a measure of interconnectedness between policy and the development of future wideband LOS SATCOM systems. This study used the MAGTF as a vignette to illustrate the dynamic and unpredictable user requirements that must be satisfied by future SATCOM systems. The need for SATCOM on the battlefield is not diminishing; consequently, components of the JCIDS framework were described because any new wideband beyond LOS SATCOM system procured in the future would be required to meet the key performance parameters and conform to oversight requirements set by the JCIDS manual. One of the underlying goals of this research was to provide an analytical foundation to help shape future USMC SATCOM operational concepts and to provide relevant information to aid in planning for future SATCOM systems acquisitions. At a minimum, we hope to at least help to shape USMC requirements that must be satisfied by new beyond LOS systems.

B. SUGGESTED AREAS FOR FURTHER STUDY

The NMS states that initiatives under development by the DoD related to information sharing and battlespace awareness include the Global Information Grid (GIG), Operational Net Assessment (ONA) Concept, the Multinational Information Sharing (MNIS) Transformation Change Package (TCP) (CJCS, 2004, p. 25). These and other similar initiatives may merit further research as to their impact on SATCOM.

The NDS directs the military to develop alternative means to accomplish the mission (Office of the Secretary of Defense, 2008, p. 22). This should apply to communication systems as well. Finding the right balance of alternative communication systems, e.g., space-based satellites, aerostats, or unmanned aerial vehicle networks, is an area that may merit future research.

The concepts presented in this thesis could be further elucidated through development of an operational scenario. In addition, such an operational scenario could form the basis for traffic analysis experiments that could help to further refine USMC

SATCOM requirements and optimize equipment utilization. Traffic could be analyzed to determine what percent is beyond LOS intra-MAGTF and what percent pulls DISN services. Additionally, further analysis might yield traffic load by warfighting function (e.g. C2, Fires, Intelligence, Logistics).

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LIST OF REFERENCES

Chairman of the Joint Chiefs of Staff (CJCS). (1998). *CJCS instruction 6250.01, satellite communications*. Washington, D.C.: Retrieved from http://www.dtic.mil/doctrine/jel/cjcsd/cjcsl/cjcsi/6250_01.pdf

Chairman of the Joint Chiefs of Staff (CJCS). (2001). *Joint publication 1-02, department of defense dictionary of military and associated terms* (July 2010 ed.). Washington, D.C.: Retrieved from http://www.dtic.mil/doctrine/new_pubs/jp1_02.pdf

Chairman of the Joint Chiefs of Staff (CJCS). (2004). *The national military strategy of the united states of america*. Washington, D.C.: Retrieved from http://www.dtic.mil/doctrine/doctrine/other/nms_2004.pdf

Chairman of the Joint Chiefs of Staff (CJCS). (2008). *CJCS instruction 6212.01E, interoperability and supportability of information technology and national security systems*. Washington, D.C.: Retrieved from http://www.dtic.mil/cjcs_directives/cdata/unlimit/6212_01.pdf

Chairman of the Joint Chiefs of Staff (CJCS). (2009). *Joint publication 3-14, space operations*. Washington, D.C.: Retrieved from http://www.dtic.mil/doctrine/new_pubs/jp3_14.pdf

Chairman of the Joint Chiefs of Staff (CJCS). (2009). *Manual for the operation of the joint capabilitites integration and development system*. Washington D.C.: Retrieved from https://acc.dau.mil/GetAttachment.aspx?id=267116&pname=file&aid=41245&lang=en-US

Chairman of the Joint Chiefs of Staff (CJCS). (2010). *Joint publication 3-0, joint operations* (Change 2 ed.). Washington D.C.: Retrieved from http://www.dtic.mil/doctrine/new_pubs/jp3_0.pdf

Chairman of the Joint Chiefs of Staff (CJCS). (2010). *Joint publication 6-0, joint communications system*. Washington, D.C.: Retrieved from http://www.dtic.mil/doctrine/new_pubs/jp6_0.pdf

Department of Defense. (2005). *Defense advanced GPS receiver (DAGR) operator's pocket guide* (Change 1 ed.) DoD. Retrieved from http://chemicaldragon.com/yahoo_site_admin/assets/docs/DAGR_Pocket_Guide_1_Jun_051.35130902.pdf

Department of the Navy, United States Marine Corps, & United States Coast Guard. (2007). *A cooperative strategy for 21st century seapower*. Washington, D.C.: Retrieved from http://www.navy.mil/maritime/MaritimeStrategy.pdf

Department of the Navy, United States Marine Corps, & United States Coast Guard. (2010). *Naval operations concept 2010*. Washington, D.C.: Retrieved from http://www.navy.mil/maritime/noc/NOC2010.pdf

DoD Directive 2045.20, Capability Portfolio Management, (2008). Retrieved from http://www.dtic.mil/whs/directives/corres/pdf/704520p.pdf

DoD Directive 5010.42, DoD-Wide Continuous Process Improvement (CPI)/Lean Six Sigma (LSS) Program, (2008). Retrieved from http://www.dtic.mil/whs/directives/corres/pdf/501042p.pdf

Forest, B. D. (2008). *An analysis of military use of commercial satellite communications*. (Master's Thesis, Naval Postgraduate School). , 69. Retrieved from http://edocs.nps.edu/npspubs/scholarly/theses/2008/Sep/08Sep%5FForest.pdf; http://handle.dtic.mil/100.2/ADA488621

Hillis, D. (2010, The age of digital entanglement. *Scientific American*, *303*, 92. doi:10.1038/scientificamerican0910-92

Marine Corps Combat Development Command, Combat Development and Integration. (2009). *Evolving the MAGTF for the 21st century*. Quantico, VA: United States Marine Corps. Retrieved from http://www.quantico.usmc.mil/MCBQ%20PAO%20Press%20Releases/090430%20CDI%20Docs/CDI_EvolvingMAGTF21stCent.pdf

Marine Corps Combat Development Command. (2010). *MAGTF communications system*. Quantico, VA: United States Marine Corps. Retrieved from https://www.doctrine.usmc.mil/

Marine Corps Combat Development Command. (2010). *Marine corps operating concepts* (3rd ed.). Quantico, VA: United States Marine Corps. Retrieved from http://www.quantico.usmc.mil/uploads/files/MOC%20July%2013%20update%202010_Final.pdf

Marine Corps Systems Command. (2009). Programs and Equipment Fact Book. Quantico, VA: United States Marine Corps. Retrieved from http://www.marcorsyscom.usmc.mil/sites/cins/Fact%20Books/CNS%20Fact%20Book%202009.pdf

Office of the President, The. (2006). *The national security strategy of the united states of america*. Washington, D.C.: Retrieved from http://edocs.nps.edu/govpubs/wh/2006/nss2006.pdf; http://georgewbush-whitehouse.archives.gov/nsc/nss/2006/index.html

Office of the President, The. (2010). *National security strategy*. Washington, D.C.: Retrieved from http://edocs.nps.edu/govpubs/wh/2010/nss2010.pdf; http://www.whitehouse.gov/sites/default/files/rss_viewer/national_security_strategy.pdf

Office of the President, The. (2010). *National space policy of the united states of america*. Washington, D.C.: Retrieved from http://www.whitehouse.gov/sites/default/files/national_space_policy_6-28-10.pdf

Office of the Secretary of Defense. (2006). *Continuous process improvement transformation guidebook*. Washington, D.C.: Office of the Secretary of Defense. Retrieved from http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA485632&Location=U2&doc=GetTRDoc.pdf

Office of the Secretary of Defense. (2008). *National defense strategy*. Washington, D.C.: Retrieved from http://www.dtic.mil/doctrine/doctrine/other/nds2008.pdf

Pillsbury, M. (2007). *An assessment of china's anti-satellite and space warfare programs, policies and doctrine*. Washington, D.C.: U.S.-China Economic and Security Review Commission. Retrieved from http://www.uscc.gov/researchpapers/2007/FINAL_REPORT_1-19-2007_REVISED_BY_MPP.pdf

Price, R. R., & McHuen, J. A. (2009). *Enabling enhanced company operations (ECO): An analysis of tactical communication requirements and solutions for a marine corps company and below*. (Master's Thesis, Naval Postgraduate School, 2009). Retrieved from http://handle.dtic.mil/100.2/ADA509274

Schmitt, E. (2004, Iraq-bound troops confront rumsfeld over lack of armor. *New York Times, the,* Retrieved from http://www.nytimes.com/2004/12/08/international/middleeast/08cnd-rumsfeld.html

Singer, J., & Clark, C. (2007). White house confirms chinese anti-satellite weapon test. *Space.Com,* , 1 September 2010. Retrieved from http://www.space.com/news/070119_china_antisat_test.html

Software Engineering Institute. (2010). *Software product lines.* Retrieved September 1, 2010, from http://www.sei.cmu.edu/productlines/

Title 10 U.S. Code Section 5063, (2007). doi:10USC5063

United Nations Treaties and Principles on Outer Space, (2002). Retrieved from http://www.oosa.unvienna.org/pdf/publications/STSPACE11E.pdf; http://www.oosa.unvienna.org/oosa/SpaceLaw/outerspt.html

United States Government Accountability Office, The. (2006). *Department of defense actions to modify its commercial communications satellite services procurement process* (Congressional No. 06-480R). Washington, D.C.: Government Accountability Office. Retrieved from http://www.gao.gov/new.items/d06480r.pdf

United States Marine Corps. (1998). *Organization of marine corps forces*. Quantico, VA: Marine Corps Reference Publication. Retrieved from http://www.quantico.usmc.mil/uploads/files/MOC%20July%2013%20update%202010_Final.pdf

United States Marine Corps. (2008). *Marine corps vision and strategy 2025*. Washington, D.C.: Retrieved from http://www.marines.mil/unit/hqmc/cmc/Documents/MCVS2025%2030%20June.pdf

United States Marine Corps. (2010). *MARADMIN 415/10, marine corps operating concepts 3rd edition*. Quantico, VA: Retrieved from http://www.usmc.mil/news/messages/Pages/MARADMIN415-10.aspx

United States Strategic Command. (2004). *Initial capabilities document for satellite communications (SATCOM) systems*. Offutt AFB, NE:

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